Preliminary apatite-fission track geochronology of the Montaña Blanca-Milocho, alkaline pluton, (NW Fuerteventura, Canary Islands, Spain)

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ABSTRACT

The mafic-ultramafic, alkaline Montaña Blanca-Milocho pluton, which is part of the northernmost outcrop of the Basal Complex of the island of Fuerteventura, Canary Islands, is spatially associated to the Jablitos alkaline-carbonatitic complex. Alkaline clinopyroxenites occurring in the periphery of both intrusive bodies bear strong petrographic, mineralogical and geochemical similarities. However, the study of a possible genetic relationship between them was so far hindered by the complete absence of geochronological data. High apatite abundances in these rocks has allowed the application of the fission track techniques as a geochronological tool. Nevertheless, in samples were perovskite occurs the lack of U in apatite, the K-Ar method had to be used. The 25 and 29 Ma fission tracks central ages obtained are well in agreement with theexpected emplacement age of these shallow intrusive rocks, and also with published and new K-Ar ages. Thus, a genetic relationship between these ultramafic alkaline clinopyroxenites is here proposed.

Key words: *alkaline clinopyroxenites, basal complex, Fuerteventura.*

INTRODUCTION

The Canary Islands archipelago is located to the West of the African passive margin, at about 100 Km offshore from Morocco (Fig. 1). In certain islands the so-called Basal Complexes, which are composed of rocks representing the early stages of evolution (submerged edifices) of these oceanic islands crop out. However, in the Fuerteventura Island, the Basal Complex presents the greatest outcropping extension and exhibits the highest petrographic variability of the exposed materials. These comprise oceanic sediments, submarine volcanic rocks, a dense dyke swarm, and alkaline-carbonatitic, mafic-ultramafic and gabbroic-syenitic intrusive rocks.

The Montaña Blanca-Milocho pluton is a mafic-ultramafic alkaline intrusive body cropping out to the NW of the island, in close spatial association with the Jablitos alkaline-carbonatitic complex (Figure 1). Despite the fact that some data on the geochronology of the alkaline-carbonatitic association in the area have been published, the Montaña Blanca-Milocho rocks still remained undated. In this work, we present preliminary fission tracks ages for representative samples of the Montaña Blanca-Milocho pluton, and compare them with new K-Ar ages made in this pluton and also with ages from Los Jablitos complex. The results reveal some interesting insights on the possible relationships between this intrusive body and its spatially associated alkaline-carbonatitic complex.

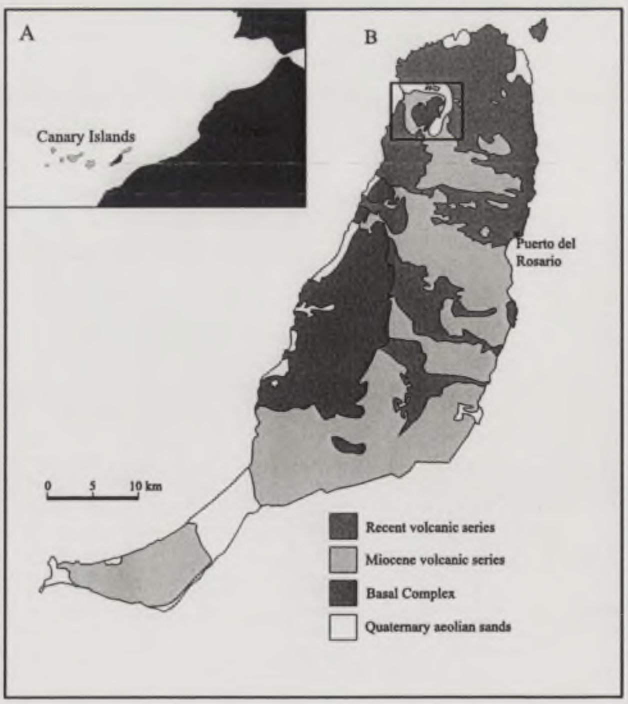

Fig. 1 A.- Geographic setting of the Canary Islands archipelago. B.- Main stratigraphic units for the island of Fuerteventura. Square: Location of studied area.

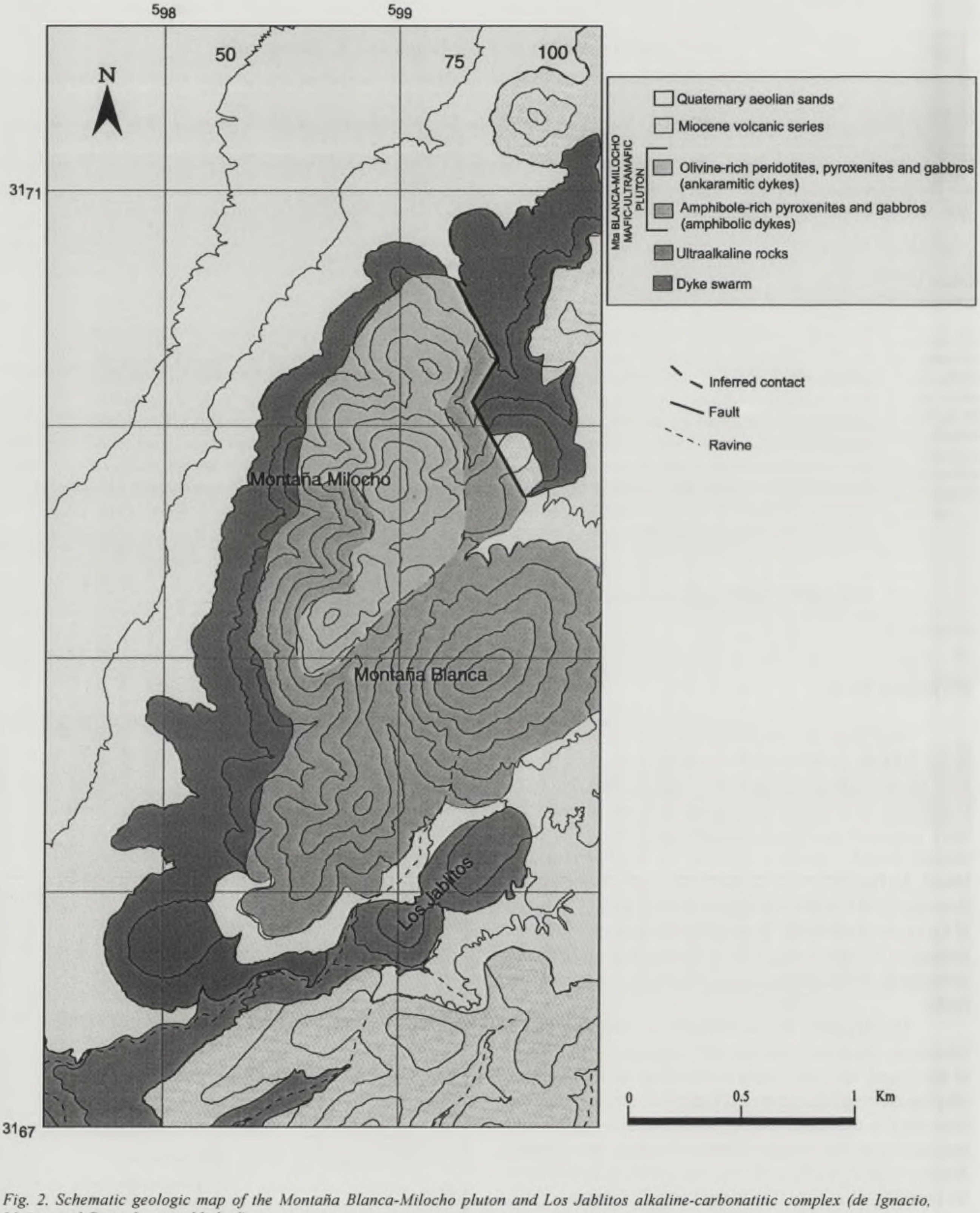

Fig. 2. Schematic geologic map of the Montaña Blanca-Milocho pluton and Los Jablitos alkaline-carbonatitic complex (de Ignacio, Muñoz and Sagredo, unpublished).

GEOLOGICAL SETTING

Three main stratigraphic igneous units have been defined in the island of Fuerteventura: The Basal Complex, which crops out only in the western part of the island, the Miocene volcanic series, and the recent (Pliocene and Quaternary) volcanic series (Fúster et al., 1980; 1984; Fig. 1).

The Basal Complex is composed of different materials, the oldest of which were overturned and folded during the early-Jurassic to late-Cretaceous. Pelagic sediments with MORB basalts at their base are also found (Steiner et al., 1998). Unconformably overlying these sediments, unfolded shallow-water sediments containing early-to-mid-Oligocene fauna occur intercalated with submarine volcanic rocks (Fúster et al., 1980; 1984). These rocks represent the onset of magmatic activity in the island of Fuerteventura. Both, the sediments and the volcanic rocks, are cut by a dense dyke swarm, which in some places makes up 100% of the outcrop, completely obliterating the country rock. The injection of this dense dyke swarm must have been the expression of a extensional period that also permits the emplacement of the alkaline-carbonatitic, and the later mafic-ultramafic and gabbroic-syenitic intrusive bodies. Both, the main phase of injection of dykes and the emplacement of the different intrusive bodies, probably took place in a relatively short time span, from late Oligocene to early Miocene (24-17 Ma; Féraud et al., 1985; Cantagrel et al., 1993).

The northernmost outcrop of the Basal Complex in Fuerteventura comprises ~ 15 Km^2. Here the Montaña Blanca-Milocho pluton and the Jablitos alkaline-carbonatitic complex are both located.

The Montaña Blanca-Milocho pluton is a zoned body comprising two facies of ultramafic-mafic, alkaline hypabissal and plutonic rocks (de Ignacio, 1999; Fig. 2). In the innermost part of the pluton, olivine-rich facies comprising wehrlites, clinopyroxenites, melanocratic gabbros and gabbros occur, whereas the peripheral facies is composed of amphibole-clinopyroxenites, amphibole-gabbros and nepheline-bearing amphibole-gabbros. The hypabissal rocks are ankaramitic, amphibole-rich and amphibole-rich nepheline-bearing dykes.

The Jablitos alkaline-carbonatitic complex, crops out to the south of the Montaña Blanca-Milocho pluton (Fig. 2). This alkaline-carbonatitic association comprises alkaline pyroxenites, subordinated alkaline gabbros, melteigites, ijolites, and small volumes of nepheline-syenites and carbonatites (Fúster et al., 1980, 1984). In addition to these, recent studies have described the occurrence of perovskite-clinopyroxenites as part of the alkaline pyroxenites assemblage (de Ignacio, 1999; Muñoz and Sagredo, 2000). These perovskite clinopyroxenites are more abundant to the periphery of the complex, close to the amphibole-clinopyroxenites of the Montaña Blanca-Milocho pluton.

PETROGRAPHIC, MINERALOGICAL AND GEOCHEMICAL FEATURES

The amphibole-clinopyroxenites from the Montaña Blanca-Milocho pluton are cumulate rocks composed of clinopyroxene (Ca-rich diopside), Ti-rich amphibole (kaersutite) and Fe-Ti oxides (magnetite and ilmenite) as ubiquitous essential phases, accessory plagioclase (labradorite-andesine), phlogopite and sphene, and variable amounts of apatite, ranging from an accessory to an essential mineral in these rocks (de Ignacio, 1999). These clinopyroxenites are associated to nepheline-bearing amphibole-gabbros by an increase in the felsic minerals (labradorite-andesine plagioclase, nepheline, and occasional K-feldspar) abundances.

The Montaña Blanca-Milocho amphibole-clinopyroxenites are characterized by high modal contents of apatite, a feature that is also distinctive in the perovskite-clinopyroxenites and ijolites from the Los Jablitos complex. The latter are also cumulate rocks made up of clinopyroxene (Ca-rich diopside) and Fe-Ti oxides (magnetite), variable amounts of perovskite, apatite and amphibole (from accessory to essential phases) and accessory phlogopite (Muñoz and Sagredo, 2000; de Ignacio, 1999). Both alkaline clinopyroxenites bear strong textural and mineralogical resemblances, the main difference between them being the occurrence of an oxide-dominated paragenesis (perovskite-Fe-Ti-oxides) in the Los Jablitos clinopyroxenites, versus a silicate-dominated paragenesis (sphene-Fe-Ti-oxides) in the Montaña Blanca-Milocho clinopyroxenites. In fact, both intrusive bodies are undistinguishable in the field, where they probably progressively grade one into each other.

Geochemically, they both reveal derivation from a TiO_2, CaO, FeO_t and P_2O_5 enriched magma, this being reflected in their observed high modal abundances of apatite, amphibole and Fe-Ti oxides.

GEOCHRONOLOGY

The above described petrographic, mineralogical and geochemical features, together with the spatial association of these alkaline clinopyroxenites in the field, actually points out to the existence of a strong affinity between them. However, the lack of geochronological data has so far hindered the study of their possible relationships.

These rocks are not easy to date due, on the one hand, to their relative recent age and, on the other hand, to their mafic-ultramafic character. Therefore, their high modal abundances of apatite made them, in principle, suitable for the application of the fission tracks as a geochronological method, provided that exhumation and cooling is been rapid enough for the apatite fission track age to be an emplacement age. As the rocks under study were emplaced at shallow crustal levels (~ 4 Km, de Ignacio, 1999) and were not subsequently affected by deformation or re-heating events, the apatite-fission tracks ages obtained would represent crystallization ages. In addition, the fission tracks technique might prove to be an interesting alternative in these to the traditionally employed K-Ar method. The latter, though sometimes useful, frequently poses several problems on the reliability of the ages obtained, because, as some authors have already discussed (Cantagrel et al., 1993; Féraud et al., 1985), the rocks under study are commonly subjected either to gains or losses of K or Ar.

Following this approach, two representative samples from the Montaña Blanca-Milocho pluton were selected for fission tracks dating: an amphibole-apatite-clinopyroxenite and a nepheline-bearing amphibole-gabbro. Two representative perovskite-clinopyroxenites from the Los Jablitos complex were also selected, but unfortunately, the occurrence of early-crystallizing perovskite, which has a very high partition coefficient for U, left the later-crystallizing apatites completely devoid of this element, thus preventing their dating by the fission track technique. For this reason, a phlogopite concentrate from a representative perovskite-clinopyroxenite from the Los Jablitos complex was dated by the K-Ar method. In addition, to contrast the fission track and the K-Ar geochronological methods, another sample of nepheline-bearing, amphibole-gabbro from the Montaña Blanca-Milocho pluton was also selected for whole-rock K-Ar dating.

ANALYTICAL PROCEDURE

Standard magnetic and heavy liquid separation techniques were use to obtain apatite and phlogopite separates.

The apatite fission tracks ages were carried out at the University of Cádiz using the external detector method and following the zeta calibration approach after Hurford and Green (1983). Irradiation with thermal neutrons was in the ANSTO facility (Australia), the neutron fluence being monitored using a Corning CN-5 glass. Personal zeta value for LB obtained using Fish Cannyon, Durango and Mt Dromedary standards is 339 ± 5.

The K-Ar ages were performed at the Centro de Geocronología y Geoquímica Isotópica of the Complutense University, Madrid. Samples were firstly treated with $(NH_4)_2CO_3$ and then reacted with a mixture of HF+HNO3 and HCl. %K was determined in duplicate in an Eppendorf Gerätebau flame Photometer, and $^{40}Ar_{rad}$ was determined by isotopic dilution in a VG Micromass 603 Gas Spectrometer. Values employed for the decay constants were those after Steiger and Jaeger (1977). Typical errors are 1% for %K, 1% for $^{40}Ar/^{38}Ar$ and 0.5% for $^{36}Ar/^{38}Ar$, all referred to 2ó.

RESULTS AND DISCUSSION

The fission tracks and K-Ar ages obtained, together with their relevant analytical parameters are given in Tables 1 and 2 respectively. The preliminary fission tracks determinations display relatively high errors due to the low uranium content in the apatites, which results from the mafic-ultramafic character. However, the obtained central ages, of 25 and 29 Ma, are well in the range expected for the emplacement of this intrusive body, and conform remarkably well with the K-Ar age of 26.7 ± 1.2 Ma of sample BM-3 (Table 2). Interestingly, the fission tracks central age of the

Sample	No. of crystals	$\tilde{n}_d$ (x10^6 t.cm^{-2})	$\tilde{n}_s$ (x10^6 t.cm^{-2})	ñi (x10^6 t.cm^{-2})	χ^2 (%)	Central age (Ma ±1ó)	U (ppm)
BM-1	23	1.039	0.0345	0.2388	99.92	25.4±3.6	2.86
BM-2	30	1.068	0.0683	0.4210	88.19	29.3±3.5	4.99

Table 1 *Fission tracks ages for representative samples of the amphibole-rich alkaline rocks of the Montaña Blanca-Milocho pluton. BM-1: amphibole-apatite clinopyroxenite; BM-2: nepheline-bearing amphibole-gabbro. Analytical parameters: ρ_d = density of tracks in the dosimeter; ρ_s = density of spontaneous tracks; ρ_i = density of induced tracks; χ^2 =probability of obtaining a χ^2 value for N-1 degrees of freedom.*

BM-1 amphibole-apatite clinopyroxenite from the Montaña Blanca-Milocho pluton, yielded a noticeably similar value to that of the K-Ar age of LJ-1 perovskite-clinopyroxenite from Los Jablitos (Tables 1 and 2). These ages are also in very good agreement with the already published ages of 23, 25 and 26.9 Ma for more differentiated terms (ijolites and carbonatites) of the alkaline-carbonatitic association in the area (Le Bas et al., 1986; Cantagrel et al., 1993; Balogh et al., 1999; Table 2).

In view of these results, we propose that a genetic relationship actually exist between the alkaline clinopyroxenites from the Montaña Blanca-Milocho pluton and from the Los Jablitos complex. Although a petrogenetic model of these rocks is clearly beyond the scope of this work, in order to support the above proposed idea, further apatite fission tracks geochronology work on slightly more

Sample	%K	$^{40}Ar^{rad}$	%$^{40}Ar_{atm}$	Age (Ma)
BM-3	1.83	1.9086 nl/g	50.99	26.7 ± 1.2
UL-1	6.77	6.9393 nl/g	86.78	26.2 ± 3
68-SC-71[1]	6.93	0.6842·10^{-5} s.c.c.g^{-1}	58.0	25 ± 1.0
Salada-1[2]	7.60	8.008·10^{-6} cm^3 STP/g	0.794*	26.9 ± 1.0
Sample	**U (ppm)**	**Pb_{rad} (ppm)**	**$^{206}Pb/^{238}U$**	**Age (Ma)**
X52[3]	309	2.485	0.0036	23.2 ± 0.2

Table 2 *Available ages for Montaña Blanca-Milocho and Los Jablitos alkaline rocks. This work: BM-3: nepheline-bearing amphibole-gabbro (Montaña Blanca-Milocho alkaline pluton); UL-1: perovskite-clinopyroxenite (Los Jablitos alkaline-carbonatitic complex). Published data: [1]Le Bas et al., (1986); [2]Balogh et al., (1999); [3]Cantagrel et al., (1993).*

differentiated terms of the Montaña Blanca-Milocho pluton amphibole-rich rocks is necessary. This will reduce the analytical errors due to the low uranium contents, and thus will make possible to place better constraints on the geochronology of this body.

CONCLUSIONS

The most primitive terms (amphibole-clinopyroxenites) of the peripheral facies of the Montaña Blanca-Milocho alkaline pluton bear strong petrographic, mineralogical and geochemical resemblances with the most primitive terms (perovskite-clinopyroxenites) of the Los Jablitos alkaline-carbonatitic complex, cropping out immediately to the south of that pluton. The high abundances of apatite in the Montaña Blanca-Milocho amphibole-rich rocks made them suitable for the application of the fission tracks technique as a geochronologic tool. Although the latter was not applicable to the Los Jablitos perovskite-pyroxenites, due to strong partition of U into perovskite, these rocks were dated by the K-Ar method. The results obtained have been contrasted for reliability by means of dating nepheline-bearing amphibole-rich gabbros of Montaña Blanca-Milocho both by the fission tracks and K-Ar methods. Preliminary fission tracks data obtained for the Montaña Blanca-Milocho amphibole-rich alkaline rocks (Table 1) yielded central ages of 25 and 29 Ma, well in the expected range for the emplacement of this intrusive body, and roughly similar to a contrasting new K-Ar age (Table 2). In addition, the respective fission tracks and K-Ar ages for the Montaña Blanca-Milocho and Los Jablitos alkaline clinopyroxenite samples, yielded very similar values of 25 and 26 Ma. These values are also in agreement with already published ages for ijolites and carbonatites of the alkaline-carbonatitic association in the area (Table 2). Thus, both the observed spatial association and the petrographic, mineralogical and geochemical affinities between these alkaline clinopyroxenites, are now confirmed by the available geochronologic data, and point out to a genetic connection between them.

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REFERENCES

Balogh, K., Ahijado, A., Casillas, R., Fernández, C. (1999): Contributions to the chronology of the Basal Complex of Fuerteventura, Canary Islands. *Journal of Volcanology and Geothermal Research*, 90: 81-101.

Cantagrel, J.M., Fúster, J.M., Pin, C., Renaud, U., Ibarrola, E. (1993): Age Miocène inférieur des carbonatites de Fuerteventura (23 Ma: U-Pb zircon) et le magmatisme précoce d'une îsle océanique (îsles Canaries). *Comptes Rendues Academie Science Paris*, 316: 1147-1153.

Féraud, G., Giannérini, G., Campredon, R., Stillman, C.J. (1985): Geochronology of some Canarian dike swarms: Contribution to the volcano-tectonic evolution of the archipelago. *Journal of Volcanology and Geothermal Research*, 25: 29-52.

Fúster, J.M., Muñoz, M., Sagredo, J., Yébenes, A. (1980): Excursión 121 A+C. Islas Canarias: Fuerteventura. Boletín Geológico y Minero, 91: 351-390.

Fúster, J.M., Barrera, J.L., Muñoz, M., Sagredo, J., Yébenes, A. (1984): Mapa y memoria explicativa de la Hoja 1106 (Pájara) del Mapa Geológico Nacional a escala 1:25.000, I.G.M.E.

Hurford, A. J., & Green, P. F. (1983): The zeta calibration of fission-track dating. *Chem. Geol. (Isotope Geosci. Sec.)*, 1: 285-317.

de Ignacio, C. (1999): La asociación de rocas intrusivas, máficas y ultramáficas, de Montaña Milocho – Montaña Blanca, en el sector NW de la isla de Fuerteventura (Islas Canarias). *Tesis de Licenciatura, Universidad Complutense*, Madrid, 138 pp.

Le Bas, M.J., Rex, D.C., Stillman, C. J. (1986): The early magmatic chronology of Fuerteventura, Canary Islands. *Geological Magazine*, 123: 287-298.

Muñoz, M., Sagredo, J. (2000): Reajustes químico-mineralógicos en las clinopiroxenitas con perovskita pertenecientes al episodio ultraalcalino-carbonatítico de la isla de Fuerteventura. *Geotemas* 1(3): 273-276.

Steiger, R.H., Jäeger, E. (1977): Subcommission on Geochronology: Convention on the use of decay constants in Geo- and Cosmochronology. *Earth and Planetary Science Letters*, 36: 359-362.

Steiner, C., Hobson, A., Favre, P., Stampfli, G.M., Hernández, J. (1998): Mesozoic sequence of Fuerteventura (Canary Islands): Witness of Early Jurassic sea-floor spreading in the Central Atlantic. *Geological Society of America Bulletin*, 110: 1304-1317.